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SPECIFICATION

INTRACAVITARY ULTRASOUND PROBE

Technical Field

The present invention relates to an intracavitary ultrasound probe for inserting the probe inside a body cavity of an object to be examined and scanning an ultrasound beam.

Background of the Invention

An intracavitary ultrasound probe is designed to observe an esophageal wall, an intestinal wall, and the like from inside by inserting the probe inside the human body from a mouse, an anus, and the like of a human body. Accordingly, a flexible section which can be freely bent along a complicated shape of tubular organ such as an intestinal canal is variously devised as mentioned below.

First, as disclosed in Japanese Patent Publication No.2790253 (first conventional technique), an ultrasound probe of electronic scan type includes an ultrasound transducer group in which a transducer array for transmitting and receiving ultrasound are arranged into a plurality of transducers and a flexible print circuit board formed in a longitudinal direction of the transducers at a predetermined angle relative to the ultrasound transducer group, in which an electrode extraction lead for acquiring a signal from each ultrasound transducer of the ultrasound transducer group is formed on one end.

As shown in Fig.4(a), the print circuit board is formed so that a section in which the ultrasound transducer group is arranged

is rectangular, and an electrode extracting section joined with the rectangular section is formed so that a surface electrode pattern is inclined at a certain angle relative to a longitudinal direction of the ultrasound transducer group. At the same time, an outer shape of the print circuit is carved out, inclining at a certain angle similar to the pattern. A portion of circuit board on which the ultrasound transducer group is mounted has adhering sections at both ends, and an adhering section is also provided on one end of the print circuit board on which the electrode pattern is formed. When the print circuit is made into a cylindrical shape and the respective adhering sections are adhered with a bond, the electrode pattern is spirally formed and a gap made between the adhering sections of the print circuit board is also formed spirally. With this construction, the print circuit board can be bent without broken.

Further, as mentioned in Fig.8(a) of the above patent document, the print circuit board divides the ultrasound transducer group into blocks, and the electrode extracting section of the print circuit board is lead in directions of θ , - θ , θ , - θ ,... in turn at each block. By thus forming the ultrasound transducer group and the print circuit board into a cylindrical shape, the print circuit board is constructed in a meshed pattern. The end connected with a lead wire is a little shifted so that the position of a land attached with the lead wire does not overlap with a land of other print circuit board in weaving the print circuit board. Further, the end connected with the lead wire is provided with an adhering section for adhering each of print circuit boards. The print circuit board being one undivided plate can be made more flexible by forming it into the meshed

pattern.

Next, as disclosed in Japanese Unexamined Utility Model Patent Publication No.Hei.5-13408 (second conventional technique), an ultrasound sensor is mounted at the end of a flexible body, and a signal from the ultrasound sensor is transmitted to a cable on the end by a flexible print circuit (FPC). The FPC is provided with a plurality of slits in its longitudinal direction and wound in its width direction. A coil spring connected to a GND of the ultrasound sensor surrounds it.

However, according to the first conventional technique, the print circuit board is formed as one plate. Even in the example of block division, the print circuit boards are adhered to each other and substantially made into one plate.

Since the print circuit board is thus formed as one plate, the range of flexibility of the intracavitary probe is limited by stiffness of the print circuit board when it is inserted into the object's body cavity, and due to this limitation of flexibility the intracavitary probe cannot be sufficiently bent along a complicatedly curving tubular organ in some cases. Accordingly, there is a possibility that a part of the intracavitary ultrasound probe touch a wall of the tubular organ to cause pain to the object, which has not been considered.

Further, according to the second conventional technique, the plurality of slits are provided on the FPC in the longitudinal direction and surrounded with coil spring 7, which occupies extra space. Therefore, it has been an obstacle to the needs of miniaturizing the probe, increasing the number of channels, and improving flexibility of the flexible section.

Moreover, an ultrasound apparatus is used not only independently for diagnosis but also with a treatment device. For example, treatment is conducted by irradiating a strong ultrasound to cauterize a cancer cell. When the ultrasound diagnostic apparatus according to the present invention is used with an electronic device like the treatment device, it is also necessary to take into consideration to deal with a noise infiltrating from the electronic device into the ultrasound probe.

Summary of the Invention

The present invention is done in consideration of the above. A first object thereof is to provide an ultrasound probe, which is miniaturized and in which the number of channels is increased, and the flexibility of a flexible section is improved.

Further, a second object of the present invention is to provide an ultrasound probe made in consideration of dealing with a noise.

Further, a third object of the present invention is to provide an ultrasound probe in which wires of the ultrasound probe are not disrupted and broken when the probe is bent, and which is easy to insert into and pull out from the body cavity.

The first object is achieved by constructing an ultrasound probe including transducers for transmitting and receiving an ultrasound having an array of a plurality of channels respectively located at several adjacent positions and a flexible circuit board connected to the respective channels of those transducers and on which a signal line for transmitting a transmission signal and extracting a reception signal to/from the transducers is printed in a longitudinal direction of the

transducer with a predetermined angle, wherein at least two channel blocks are formed on the flexible circuit board by dividing the plurality of channels, and the respective channel blocks are spirally wound.

Further, the second object is achieved by constructing an ultrasound probe in which the above two or more channel blocks formed on the flexible circuit board are surrounded with an insulating material and a first shield material, or with an insulating material evaporated on its surface one of a layer of metallic powder of gold, silver, copper, brass, aluminum, and the like or a combination thereof. Further, the second object also can be achieved by arranging a single second shield material for covering an outer circumference of the bundled channel blocks of the flexible circuit board. And further, it also can be achieved more effectively by constructing an ultrasound probe in which each channel block formed on the flexible circuit board are covered with an insulating material and a first shield material, or with an insulating material evaporated on its surface a layer of metallic powder of gold, silver, copper, brass, aluminum, and the like or a combination thereof, and further arranging a second single shield material or protective material, or an insulating material evaporated on its surface a layer of metallic powder for covering the outer circumference of the bundled channel blocks of the flexible circuit board.

The third object is achieved by providing either a protection material or a second shield material for covering two or more channel blocks bundled on the flexible circuit board, whereby the channel blocks are not disrupted. Further, handling is improved by making the protection layer using flexible material,

and the probe becomes easy to grip and operation becomes easy for an operator by providing the stiff section and the flexible section.

Brief Description of Drawings

Fig.1 is a diagram showing the state that a part of a flexible circuit board of an ultrasound probe according to the present invention is spirally wound. Fig.2 is a diagram showing a transducer unit of the intracavitary ultrasound probe, a flexible circuit board to which slits are made, and a joint unit of cable according to present invention. Fig.3 is a diagram showing the bending state of the flexible intracavitary probe containing the flexible circuit board. Fig.4 is a diagram showing a positional relation among a flexible tube used as a protection material for containing the flexible circuit board and the like and a plurality of flexible circuit boards. Fig.5 is a schematic diagram showing the bending state of the flexible circuit board extending from the portion connected with the transducer. Fig.6 is a diagram showing an example of application of the present invention to a convex type ultrasound probe. Fig.7 is a diagram showing an example of application of the present invention to a transesophageal ultrasound probe. Fig.8 is a diagram showing an example of application of the present invention to an abdominal ultrasound probe. Fig.9 is a diagram showing the state that the flexible circuit board is covered with a resin tube used as an insulating material. Fig.10 is a diagram showing the state of the flexible circuit board formed as a duplex circuit board. Fig.11 is a diagram showing an example of covering each flexible circuit board with a first

shield material. Fig.12 is a diagram showing a first shield material and a flexible circuit board inserted into the flexible tube used as a protection layer containing parts of Fig.11, in which the first and second shield materials are electrically connected.

Best Mode for Carrying Out the Invention

Hereinafter, embodiments of the present invention will be described in detail with reference to the accompanying drawings.

First, an intracavitary ultrasound probe called radial type is taken as an example. Fig.2 is a diagram showing a connecting relation among a transducer unit, a flexible circuit board, and a cable of the radial type intracavitary ultrasound probe.

Transducer unit 1 is formed so that a transducer element corresponds with each of a plurality of close positions of transmission and reception (hereinafter referred to as "channel"). One end of flexible circuit board 2 is connected to each channel of the transducer elements, and the other end has a cable connecting section 5 so that a signal line can be connected to a cable for transmission and reception. On this flexible circuit board 2, signal pattern 4 is formed so that a signal can be transmitted and received between transducer unit 1 and cable connecting section 5, and each signal pattern 4 is electrically insulated. Further, flexible circuit board 2 is not formed by one circuit board but formed so that a part of all channels is bundled into blocks divided by slit 3. Further, it is preferable to provide a ground so as to sandwich signal pattern 4 because crosstalk in signal transmission can be thereby

prevented.

Further, each divided portion of flexible circuit board 2 is spirally wound at angle θ relative to transducer unit 1. However, because the flexible circuit board is flexible, the angle is not exactly determined but has a certain range. Accordingly, the slit may be formed roughly at angle θ.

Next, Fig.1 is a diagram showing the state of the spirally wound flexible circuit board of the intracavitary ultrasound probe according to the present invention.

As shown in the figure, transducer unit 1 is rolled and fixed. It may be fixed not only by adhesion but also by setting it in a formwork and the like. Flexible circuit board 2 is spirally wound at intervals of gap g. At this time, gap g is determined depending on the extent of bending the body covering flexible circuit board 2. Here, the principle thereof will be described with reference to Fig.3. Fig.3 is a diagram showing the principle for calculating gap g. When it is hypothesized that the body is bent so as to draw an arc, given that the radius is R, the diameter of the body is d, and the width of one flexible circuit board is a (see Fig.1), gap g is calculated by formula (1).

$g = a \cdot d / R$...(1)

A process of deriving this formula will be described. When the flexible section is bent at θ°, in Fig.3 the length of inner arc CD of the flexible section bent to the maximum is $2\pi R\theta/360$, and the length of outer arc AB of the flexible section bent to the maximum is $2\pi(R+d)\theta/360$. Accordingly, a difference between outer and inner arcs is $2\pi d\theta/360$. Here, number n of spiral portions in the flexible section (winding number) is calculated by dividing $2\pi R\theta/360$ being the length of inner arc

of the flexible portion bent to the maximum by width a of the flexible circuit board, the result being $2\pi R\theta/360a$. Gap g is the number obtained by dividing the difference between the arcs of the outer and inner flexible section by the winding number of the flexible circuit board, which is expressed as $g=ad/R$. Meanwhile, a relation between width a of the flexible circuit board and gap g is $a \geqq g$.

In this manner, gap g of flexible circuit board 2 is determined, and flexible circuit board 2 is arranged in a body referred to as a flexible tube made of synthetic resin, synthetic rubber, or the like on the basis of its division number as shown in a cross sectional view of Fig.4. Fig.4 is a diagram showing a relation of arrangement between the flexible tube and a plurality of flexible circuit boards contained therein. Fig.4(a) shows an example of the flexible circuit board divided into two, each of which is spirally wound. Fig.4(b) shows an example of division into three, Fig.4(c) shows an example of division into four, and Fig.4(d) shows an example of division into five. When the circuit board is divided into six or more, close-packed arrangement is formed.

Next, how the flexible circuit board is bent will be described. Fig.5 is a diagram showing modes of the flexible circuit board from an extraction point (point connected with elements) to a flexible section. The flexible circuit board is contracted as shown in Fig.5(a) when it does not have to be bent. When it has to be bent, it can be bent as shown in Fig.5(c) since it has an extensible structure shown in Fig.5(b).

Meanwhile, the intracavitary ultrasound probe includes a convex type, a transesophageal type, and an abdominal type in

addition to the radial type, examples of application of which will be mentioned.

Fig.6 is a diagram showing an example of application of the present invention to the convex type ultrasound probe, Fig.7 is a diagram showing an example of application of the present invention to the transesophageal ultrasound probe, and Fig.8 is a diagram showing an example of application of the present invention to the abdominal ultrasound probe. The radial type has an FOV in a cross sectional direction of the inner surface of a tubular organ. On the other hand, the convex type has a rectangular FOV with respect to an inner wall. As shown in the figure, many of transesophageal type have, e.g. a circular FOV as shown in Fig.7, or a polygonal FOV. Although the abdominal type also has a rectangular FOV similar to that of the convex type, it is not inserted into an object to be examined along the tubular organ but inserted into a hole punched on a body surface of the object. Since the probe is difficult to handle if the portion griped by the object is flexible tube 8, it is made as hard section 12.

Further, as shown in Fig.9(a), each of the flexible circuit boards may be individually covered with resin tube 13 so as to react to bending stress. A cross-sectional view of the body covered with resin tube 13 is arranged as shown in Fig.9(b), which shows an example of division into five.

Further, the flexible circuit board is constructed by duplex print circuit boards as shown in Fig.10, in which a signal line is connected with one layer and GND layer 14 is provided over the other layer. Since a pattern of signal line can be integrated on the signal line layer, this construction is effective in increasing

the number of channel and resolving crosstalk. Fig.10(b) is a cross sectional view of the body in which the duplex flexible circuit boards are arranged, which shows an example of division into five.

According to the above described embodiment, the limitation of the flexible range of the flexible circuit board (print circuit board) existing in the state that the flexible circuit board is made as one plate is released, the degree of flexibility is properly ensured, and miniaturizing of the probe and increase of the channel number are enabled since a coil spring is not used.

Further, the channels of the flexible circuit board may be divided equally or unequally.

Further, since the value of gap is properly determined, a signal line inside the flexible circuit board does not easily broken.

Further, it is needless to say that the present invention may be applied to a combination of various modes of a flexible circuit board covered with a resin tube, that formed by two or more multiple layers of pattern, and the like.

Next, an embodiment of dealing with shield will be described.

Fig.11 and Fig.12 show examples of structure of an FPC covered with a shield material.

First, as shown in Fig.11, transducer unit 1 is made into a cylindrical shape, and each section 2 of the FPC divided by slits is processed into a spiral shape. Each section of FPC 2 is insulated with resin tube 13 being an insulating material. The outside of resin tube 13 is attached with first shield material 20, such as a conductive tape. The shield material is made of

conductive spiral tube or cross tube having high flexibility and high shield effect.

Next, as shown in Fig.12, a set of the FPC assembled in Fig.11 is contained within flexible tube 8 being a protection material via second shield material 21 covering the outside of cable. Second shield material 21 may be made of the same material as first shield material 20, or a braided shield used in a coaxial cable. Because both first shield material 20 and second shield material 21 are made of conductive material, they are electrically connected by arranging them so as to touch each other. By connecting first shield material 20 and second shield material 21, shield efficiency is further improved in this construction.

Further, instead of using the above first shield material, metallic powder of gold, silver, copper, brass, aluminum, and the like may be evaporated onto the surface of the resin tube being a insulating material which protects the spiral flexible circuit board.

It is also possible to arrange only second shield material 21 or the protection material, or both of them on the outer circumference of the bundled sections spirally wound of the above flexible circuit board without interposition of the insulating material and first shield material 20. In this case, by evaporating metallic powder of gold, silver, copper, brass, aluminum, or the like onto the surface of the protection material used as insulating material, the protection material serve as the second shield material.

Further, although a detailed description is omitted, it is needless to say that the present invention is applicable to every

kind of intracavitary ultrasound probe including the convex type ultrasound probe mentioned in Fig.6 and an ultrasound probe mentioned in Fig.7.

As described above, by constructing an ultrasound probe so as to install a shield on a spiral flexible circuit board using a material having a shield effect, it becomes possible to shut off an electromagnetic wave noise affecting an ultrasound image generated by other electronic devices and medical devices used at the same time when a signal is extracted from a transducer to an ultrasound probe, whereby a clear ultrasound image can be provided.